

NDIC Grant Application
Antelope Valley Station CO₂ Capture FEED Study
Response to Peer Review Comments

Reviewer 08-15

4. Contribution

Comment; Since the work is so specific, the scientific/technical contribution is likely to be small.

Basin Electric's Comments:

The FEED study is specific to Antelope Valley Station; however, the information gained in the FEED study will have application to all of the existing coal-based electric generation facilities in the state. Issues include: How to handle the SO₂ levels for the ammonia technology to work properly? – these criteria would be needed for amine applications as well. How do you get the steam that is necessary for the regenerative process and have the least impact on the station generation capacity? How do you handle new emissions points with respect to the operating permit? All of this information will be transferable to other existing facilities as well and provide a solid basis for building new lignite-based generation with carbon capture technology.

Using carbon dioxide captured from The Antelope Valley Station for EOR will allow the large scale demonstration of carbon capture technology that will lead to its commercialization. Doing the FEED study is the first step in the process to being proactive in solving what to do with CO₂ emissions and ensuring a pathway for carbon management for the lignite industry.

Long-term this project is intended to be the source of CO₂ for the Plains CO₂ Reductions (PCOR) Partnership which will validate the sequestration of CO₂ used in enhanced oil recovery (EOR). PCOR will develop cost-effective approaches to monitoring, mitigation and verification. Selling CO₂ for EOR does provide an economic benefit for the added costs and risks of carbon capture technology. Using CO₂ for EOR in North Dakota provides a bridge to understanding long-term sequestration in other geological formations such as saline aquifers and un-mineable coal seams.

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Equipment Purchase

Comment: The level of detail in the proposed budget is insufficient to determine what equipment purchases are proposed. In fact, the level of detail is insufficient to justify any cost item.

Basin Electric Comments:

The FEED study will determine what equipment to purchase in regards to size, specifications and capacity. There will be no equipment purchased in the FEED study phase.

5. Awareness

Comment: "There is no discussion in the proposal about the technical issues associated with SO₂ and CO₂ capture from flue gas derived from combustion of North Dakota lignite, the relative capital cost, the technical advantages/disadvantages, the CO₂ capture cost of these technologies compared to other technical approaches for CO₂ capture such as the use of amine scrubbers.

Therefore the technical contribution of this work to the general subject of capturing CO₂ in flue gas generated by combustion of North Dakota lignite is likely to be small."

Basin Electric Comments:

Basin Electric went through a lengthy evaluation process before selecting the technology for this demonstration project. There are countless technologies that are being discussed to capture CO₂ from the combustion of coal to produce electricity. Post combustion capture technologies vary from passing flue gas through algae, membranes, or capturing CO₂ through a solvent such as amine or ammonia. Other CO₂ mitigation technologies include oxy-fuel combustion or integrated gasification combined cycle processes. There are several more concepts and ideas all ranging in different stages of development from concept to laboratory testing to field testing. At this time, it seems that post combustion CO₂ capture is the most reasonable and most developed technology to reduce CO₂ emissions from an existing or new facility.

On June 1, 2007, Basin Electric issued the first competitive Request For Proposal (RFP) for a CO₂ capture demonstration project. This RFP was sent to ten companies and placed on the Basin Electric website to be available for any technology provider to submit a proposal. Six proposals were received in September of 2007 from the following companies; HTC Purenergy, Mitsubishi Heavy Industries, Fluor, Cansolv, Powerspan, and Alstom. Due to the proprietary nature of the specific processes and the fact that Basin Electric has confidentiality agreements with some of these technology providers, some information comparing the processes cannot be shared. However, the following attempts to explain the advantages and disadvantages of the proposed technologies.

All of the proposed CO₂ capture technologies require very low levels of SO₂ coming into the system. Therefore, all of the proposals included a polishing scrubber to further reduce the amount of SO₂ in the flue gas slipstream to about 10 ppm or less. If the SO₂ is not taken out of the flue gas prior to the CO₂ capture process, the SO₂ will be captured in the CO₂ capture vessel which degrades the performance of the solvent and increases the cost to capture CO₂.

Of the six CO₂ capture processes considered, four use amine and two use ammonia. Amine capture technology has been proven to capture CO₂ out of coal fired flue gas streams at small scales while the use of ammonia is relatively new. In either of these post combustion CO₂ capture technologies, the CO₂ is captured from the flue gas and transferred into a liquid consisting of water and either amine or ammonia. Then this liquid containing the CO₂ is brought to another vessel to drive off the CO₂ from the liquid. Steam is required to separate the CO₂ gas from the liquid and in short, CO₂ captured with ammonia takes much less steam to then CO₂ captured with amine. Once the CO₂ is separated from the liquid, the CO₂ gas is cleaned up and compressed for transportation while the liquid is re-circulated back to make contact with the flue gas and collect more CO₂.

HTC Pureenergy, Mitsubishi Heavy Industries, Fluor, and Cansolv all proposed amine CO₂ capture systems while Powerspan offered an ammonia capture system and Alstom offered their chilled ammonia capture system. The four amine systems proposed different polishing SO₂ removal technologies, but similar CO₂ capture technologies. The amine post combustion CO₂ capture is a more proven technology with small pilot plants in operation. However, the energy requirements in these four technologies were significantly higher than the requirement Powerspan proposed.

After clarification and evaluation, Alstom's process seemed to impact the current operations about the same as an amine system would. The reason for this impact is the large electrical load required by the process. Alstom's chilled ammonia CO₂ capture technology is in a similar stage of development when compared to Powerspan. Finally, Alstom's expected removal rate was significantly less than the 90% removal rate proposed by the other five technologies evaluated.

The Powerspan process was evaluated the best post combustion CO₂ capture process for several reasons. When compared to the other post combustion CO₂ capture technologies, the Powerspan process proposed the least cost per ton of CO₂ captured. Since the expected capital cost for the six technologies was similar, this cost reduction is in large part due to the expectation that Powerspan's process will result in much less impact to the existing net generation than the other proposed technologies.

In addition, the Powerspan process will not produce a waste stream. Alstom's process would share this advantage as an ammonia capture technology while the amine capture systems produce a waste stream of contaminated amine. Whenever contaminants such as SO₂ pass into amine based CO₂ capture processes, the solvent is contaminated. In the Powerspan process the ammonia reacts with the SO₂ producing ammonium sulfate which is a marketable byproduct. The Great Plains Synsfuels Plant (GPSP) has the facilities to convert the ammonium sulfate into a saleable dry fertilizer. The amine reacts with contaminants such as SO₂ that produces heat stable salts. This means that the contaminated amine needs to be purged from the system and disposed of since this is not a marketable product. Without purging this contaminated solvent from the system, CO₂ capture performance will degrade. For example, if the SO₂ has attached to the solvent and won't release, this molecule of solvent will not capture CO₂.

The above evaluated advantages of the Powerspan system when compared to other post combustion CO₂ capture should be applicable to other coal-based power plants as well. Site specific advantages to Basin Electric's facilities include the ability of the Powerspan process to integrate smoothly into the existing infrastructure at the Antelope Valley Station and GPSP. As stated, the GPSP plant produces ammonia and processes ammonium sulfate. The Powerspan process will be provided ammonia from the GPSP and the ammonium sulfate created in the Powerspan process will be sent to the GPSP for processing. Great synergies exist between the Powerspan process and the GPSP.

7. Project Management

Comment: "In my opinion, this is a major weakness of the proposal. There is a schedule proposed but no details regarding milestones, a financial plan, a plan for communications among investigators and subcontractors. This is definitely a shortcoming for such a major project (\$5.4 million)."

Basin Electric Comments:

Organization, communication, and a realistic work plan are key to bringing a project in on time and within budget. There is an organizational chart attached that identifies the key individuals that will be supporting the work in the FEED study and the project development as a whole. Nearly all of these individuals have a great deal of experience in their respective fields and bring an immeasurable contribution to the project.

The project manager, Jim Sheldon, will rely on these key individuals to carry out the detailed work in these respective areas. Mike Paul, who is the Vice President of Engineering and Construction at Basin Electric, will oversee project progress and provide consultation and guidance throughout the project. Upon review of the organizational chart, you will see key personnel from all applicable areas within Basin Electric that have been assigned to be part of this project team. There are still several others that will support these key individuals and contribute to the project on an as needed basis.

Along with the organizational chart, a graphic depicting the communication flow is attached. The personnel identified in the communication chart will serve as points of contact between the different organizations involved in this large project. The communication path between Basin Electric and Powerspan can be seen between Jim Sheldon and Rob Sullivan. In addition to the Powerspan internal coordination, Rob Sullivan will communicate directly with project managers of Burns & McDonnell, Stantec, and any other firms who will be conducting services external to Powerspan. Jim Sheldon will coordinate the efforts at Basin Electric along with external communication such as providing progress reports to the NDIC. This defined communications structure will lay the foundation for a successful project.

To effectively communicate the progress of the project, Jim Sheldon will be providing one progress report to the NDIC about three months into the study. This report will give an update of the actual progress to date and expenses incurred compared to the projected progress and cash flow. Upon completion of the FEED study, a final report will be prepared and delivered to the NDIC containing the key results of the FEED study.

Due to confidentiality agreements and the proprietary nature of this technology, some technical details will not be included in the reports. Realizing the NDIC is most interested in how this project relates to the lignite industry of North Dakota, project specific details not included will likely have a minimal impact. Basin Electric will work with Powerspan to reveal as much information as possible without infringing on existing confidentiality agreements and placing Powerspan's intellectual property in danger.

A work plan with realistic, obtainable goals is crucial to a successful project. The grant application included a list of the expected tasks and deliverables for those tasks. Attached, you will find a Gantt chart schedule that displays these tasks as they are expected to occur

throughout the FEED study. This Gantt chart displays the defined FEED study tasks, the expected amount of time that is required to achieve the defined deliverable for each task, and the sequence that the work must be conducted to accomplish the goals in the six month study. From this plan, an estimated cash flow has been generated to predict the expenditures for the project on a monthly basis. The details of this predicted cash flow are attached for your consideration.

This well thought out and documented work plan will serve as the management tool to judge the progress and determine if the project is on a successful glide path or if adjustments are necessary. There will almost certainly be deviations from the plan, but the work plan will serve as a map leading the way to successful completion of the project.

Overall Comments and Recommendation:

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“...The operation of the Burger plant in Ohio is important. The FEED 120 MW proposed AVS site is a reasonable scale-up from the 50 MW Burger Plant. ...”

Just to clarify, at the Burger Station there is a 50 MW Powerspan ECO unit operating. Powerspan's ECO system removes several pollutants including NO_x, SO_x, and Mercury. In addition to that system, Powerspan is building a 1 MW ECO₂ pilot plant which will capture CO₂ from a smaller stream of flue gas down stream of the 50 MW Powerspan ECO unit.

The Antelope Valley Station CO₂ capture demonstration project will use Powerspan's ECO–SO₂ system which is very similar to the ECO system except it takes SO₂ out of the flue gas without effecting NO_x. After passing through the ECO–SO₂ system, the flue gas will pass through the ECO₂ system where 90% of the CO₂ will be removed.

The scale up from Powerspan's 1 MW CO₂ capture pilot plant to this 120 MW demonstration project is significant. However, Basin Electric believes that it is a reasonable scale up in this technology development. This was further confirmed when Basin Electric hired Worley Parsons to receive a 3rd party opinion regarding scale up. Worley Parsons' conclusions concurred that the scale up risk is reasonable and manageable.

“If this phase is successful, and a decision to proceed is reached, will the participants request additional NDIC/LRC funds?”

Yes. Upon project commitment, Basin Electric plans to apply for a Vision 21 grant to aid in the funding of this project.

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“What are the specific issues associated with capturing CO₂ from flue gas resulting from combustion of North Dakota lignite?”

Carbon Dioxide makes up a much larger percentage of the flue gas as a combustion product when compared to other pollutants such as SO_x or NO_x . This large quantity to capture and compress is one of the reasons that CO_2 capture burdens the cost of electricity as much as it does. Of the six technologies evaluated, all of the CO_2 capture systems require the incoming flue gas to be nearly free of particulate and SO_2 . This is a challenge to our power plants burning North Dakota lignite and would likely require all of the units to further reduce the SO_2 concentration in their flue gas stream before entering into a post combustion CO_2 capture process. Comment to consider: Because of lignite's low quality, more CO_2 is generated per MW of electricity produced when using lignite as the fuel compared to other higher quality coals.

"How do the ECO- SO_2 and ECO technologies deal with those issues? Are there advantages of these technologies in dealing with those issues relative to other approaches?"

The ECO – SO_2 system acts as a polishing scrubber and it further reduces the SO_2 and any particulate that may have made it through the baghouse. Then the ECO $_2$ system captures the CO_2 . The fact that CO_2 makes up a larger portion of the flue gas cannot be changed. However, Powerspan's process seems to provide the least cost and least energy impact approach to capturing CO_2 of the six technologies evaluated. In addition, there are no waste streams created with the Powerspan process where in an amine based system there is a stream of spent amine that needs to be treated and/or disposed of.

"How does the CO_2 capture cost of the ECO $_2$ technology compare with other technologies?"

The six technologies investigated (amine and ammonia CO_2 removal) seemed to have very similar capital costs with the Powerspan process predicting much less impact to the existing power plant and lower operating costs compared to the other five.

"How does the auxiliary power requirement of these technologies compare with other technologies?"

The advantage of the lower Powerspan process operating cost lies in the fact that much less steam, auxiliary power, and reagent use is expected when compared to the other five technologies investigated. The amine process reportedly takes a great deal more steam to separate the CO_2 gas from the amine liquid in the regenerator. While Alstom's ammonia process requires less steam than amine, the process seems to require a great deal of electricity.